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A Compilation of Results from Shallow Soil-Gas Surveys of the Subsurface Disposal Area for Operable Unit 7-08

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This report is a compilation of the results of five shallow soil-gas surveys conducted at the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex. The surveys were conducted in 1987, 1992, 1999, 2000, and 2001 for the general purpose of characterizing the nature and extent of volatile organic compound sources at the SDA. Summaries of the five shallow soil-gas surveys are contained within the main body of this report, while a more detailed documentation of each survey is included in the appendices. This report will serve as a central reference document for previous shallow soil-gas surveys performed at the SDA. Information may be added to this report as future surveys are conducted.

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FIGURES

ACRONYMS

INEEL	Idaho National Engineering and Environmental Laboratory
PCE	tetrachloroethene
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethene
VOC	volatile organic compound

A Compilation of Results from Shallow Soil-Gas Surveys of the Subsurface Disposal Area for Operable Unit 7-08

1. INTRODUCTION

From 1952 to 1970, mixed and hazardous waste was buried in shallow pits and trenches at the Subsurface Disposal Area (SDA). The SDA is part of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL) in southeastern Idaho (see Figure 1). Some of the waste buried in the SDA contained volatile organic compounds (VOCs). The majority of VOCs were processed as semi-solidified sludge (743-series), placed in barrels lined with plastic and buried in the late 1960s. The primary VOC in 743-series sludge is carbon tetrachloride (CCl_4) with lesser amounts of 1,1,1-trichloroethane (1,1,1-TCA), trichloroethene (TCE), and tetrachloroethene (PCE) (Miller and Varvel 2001). It is believed that many of the 743-series sludge barrels have degraded, allowing VOCs to migrate into the subsurface and form a large subsurface plume as indicated by deep soil-gas and groundwater measurements. Environmental Restoration personnel have implemented remediation strategies to remove and treat these VOCs.

Several investigations, including five shallow soil-gas surveys, have been performed to characterize the nature and extent of VOC contamination at the SDA. The first soil-gas survey, conducted in 1987, covered a large area and used a coarse sampling grid. Subsequent soil-gas surveys conducted in 1992, 1999, 2000, and 2001 have been increasingly focused to more accurately monitor spatial and temporal changes in soil-gas vapors emanating from the buried waste.

The purpose of this report is to provide a single reference containing the details of the five soil-gas surveys conducted at the SDA and to provide a central document for incorporating and comparing data from future soil-gas surveys and other characterization efforts. The five soil-gas surveys are briefly summarized in the main body of this report. Detailed documentation of each survey is included in the appendices.

2. 1987 SHALLOW SOIL-GAS SURVEY

The 1987 shallow soil-gas survey was conducted to determine the location and relative concentration of selected chlorinated and aromatic VOCs in and adjacent to the SDA. VOCs had been detected in the groundwater near the SDA and it was suspected that buried waste at the SDA was the source of the contamination. Golder Associates of Redmond Washington performed the soil-gas survey in November 1987. Golder took 145 gas samples from 133 shallow sampling locations in and immediately surrounding the SDA. Of the 133 locations, 112 were based on a regular grid (61-m [200-ft]) spacing and most of the 21 other locations were selected to better define the areas where high levels of VOCs were detected.

Samples were collected by first drilling a shallow hole into the surficial sediments and then driving a slightly oversized probe to the base of the hole. The depth of the holes ranged from 20 to 89 cm (8 to 35 in.) with most of the holes being 76 cm (30 in.) deep. However, the depth of several holes was significantly less because of drilling difficulties. After driving the probe, a rod was inserted into the probe to dislodge the probe drive point and allow soil-gas to enter. The annular space of the probe was sealed at the surface with clay and the probe was purged for 1 to 2 minutes at 2 to 3 L/minute, using a pump connected to the probe with flexible tubing. Samples were removed from the tubing with a syringe and analyzed with an HNU Model 321 field gas chromatograph for 10 chlorinated and two aromatic compounds.

Of the 12 compounds screened by the survey, only CCl_4, TCE, PCE, and 1,1,1-TCA were identified. It should be noted that chloroform ($CHCl_3$) results were not reported because $CHCl_3$ elution was obscured by CCl_4 and 1,1,1-TCA elution on the chromatogram. The results of the survey showed relatively high concentrations of CCl_4 with lesser levels of TCE and 1,1,1-TCA and even lesser levels of PCE. The highest concentrations detected were 365 ppmv for CCl_4, 128 ppmv for TCE, 57 ppmv for 1,1,1-TCA, and 6 ppmv for PCE. The CCl_4 was primarily located in three areas: (1) the west end of Pit 10, (2) the junction of Pits 4 and 6, and (3) the southern end of Pit 9. Lesser concentrations were detected over Pit 5.

Areas of CCl_4 concentration correlated well with areas of TCE and PCE concentration. The correlation between CCl_4 and 1,1,1-TCA, however, was not nearly as good. A significant portion of the samples high in CCl_4 did not contain detectable levels of 1,1,1-TCA and vice-versa, while some samples contained equal concentrations of both compounds. The areas of highest 1,1,1-TCA concentration were Pit 3, the west end of Pit 4, the southeast corner of Pit 5, and the southeast corner of the SDA south of the active low-level waste disposal pit. All of these areas were low in CCl_4 concentration. While these data suggest there may have been another source of 1,1,1-TCA besides 743 sludge, concentrations of 1,1,1-TCA anywhere in the SDA are still much less than measured CCl_4 concentrations.

The survey was successful in that it was able to identify key compounds contributing to subsurface contamination and generally identify their burial locations. The original report of this activity is contained in Appendix A. In addition, a table of CCl_4 results converted to ppmv from the original data, which was reported in μg/L, has been created and included in Appendix A as Table A-1. A map of detected values of CCl_4 is also included as Figure A-1 (see Appendix A).

3. 1992 SHALLOW SOIL-GAS SURVEY

The purpose of the 1992 shallow soil-gas survey was to collect additional soil-gas data to either support or refute the data from the 1987 survey. The 1992 survey was performed by INEEL employees in January and February when the ground was frozen. The 91 sample locations used for the 1992 survey were a subset of the 1987 survey locations. Sample locations were restricted to inside the SDA and focused on areas around pits where VOCs were detected in the 1987 survey.

The sample port installation process was similar to the process used in 1987, and consisted of manually hammering coring devices into the soil, inserting Teflon tubes, and sealing the annulus with clay at the surface. After a 30-second purge time, samples were retrieved into a Tedlar bag and analyzed using a Scentograph portable gas chromatograph. Analysis occurred within 1/2 hour of sample collection. Samples were analyzed for CCl_4, TCE, and $CHCl_3$. The gas chromatograph was also used to identify four tentatively identified compounds: trans 1,2-dichloroethene, 1,1,2,2-tetrachloroethene, toluene, and m-xylene.

Twenty-one of the 91 sample locations had positive detections for at least one of the compounds. Eight of those 21 locations also indicated the presence of tentatively identified compounds. Carbon tetrachloride concentrations were highest in the southern end of Pit 9 (255 ppmv), while the highest concentration of TCE was at the eastern end of Pit 2 (52 ppmv). The CCl_4 concentration at the eastern end of Pit 2 was 111 ppmv. The highest concentration of $CHCl_3$ was near the west end of Pit 10 (7 ppmv).

Overall, the results of the 1992 shallow soil-gas survey were similar to the results of the 1987 survey with a few notable exceptions. First, the percentage of detects (positive analyses) was lower for the 1992 survey. This was unexpected, given that during the 1992 survey, locations outside the SDA where concentrations are lower were not sampled. The difference could be the result of (1) different sampling procedures, (2) a different analytical instrument, or (3) differences in the seasons (late fall versus winter). The second notable difference between the two surveys is the difference in CCl_4 and TCE concentrations over the eastern end of Pit 2. Relatively high concentrations of CCl_4 and TCE were measured at this location in 1992 (111 and 52 ppmv respectively) compared to 2 ppmv for both CCl_4 and TCE measured during the 1987 survey. The results of both surveys are an indication that VOCs were buried at this location even though Pit 2 was closed when the 743-series sludge was disposed. The VOCs could have come from Rocky Flats, but shipped prior to the time when VOCs were processed into 743-series sludge, or they could have come from another waste generator.

The original engineering design file documenting the 1992 soil-gas survey is contained in Appendix B.

4. 1999 SHALLOW SOIL-GAS SURVEY

The purpose of the 1999 shallow soil-gas survey was to obtain refined data about VOC concentrations and locations in specific areas, and obtain a baseline set of soil-gas data for evaluating future changes in source behavior. Better knowledge of VOC concentration and location would help guide more intrusive source characterization efforts, such as excavation coring or probing, and provide data for treatability study tests.

Previous studies by Magnuson and Sondrup (1998) and Miller and Navratil (1998) had suggested the original inventory of CCl_4 in 743-series sludge was larger than previously reported. A larger inventory would have implications for source treatment, and for the vapor vacuum extraction system operated by Operable Unit 7-08. The 1999 survey was the first high-resolution soil-gas survey proposed to provide a general indication of source strength and behavior. Comparisons to subsequent surveys would provide a general indication of source strength and trend in release rate. Furthermore, it was thought that in lieu of intrusive methods previously mentioned, shallow soil-gas surveys were likely the best method to gauge source behavior.

The survey focused on a much smaller region than the two previous surveys and used a closer spacing on sample locations for increased resolution. The proposed sampling grid consisted of 247 locations on roughly 9-m (30-ft) centers that covered all of Pit 10 and the eastern portion of Pit 4. Accessibility problems and drilling difficulties limited the number of ports that were installed to 183 (see Figure 2). Ports were installed by means of an electronic hammer drill to a depth of 96 cm (30 in.) during the late fall of 1998. Point tips were connected to Teflon tubing and to the ends of 3-ft (91-cm) drive rods. The rods, when connected to the hammer, pounded the tips into the soil. At 96 cm (30 in.), the rods were retracted, leaving the tips and tubes anchored in the soil. No attempt was made to seal the annulus of the tubes from the atmosphere.

Most of the ports for the 1999 shallow soil-gas survey were installed in 1998, but the samples were collected and analyzed in two separate events in 1999. The first sampling event occurred in January 1999 and consisted of 37 samples collected from ports over Pit 4, excluding Row B (see Figure 2). Row B was added just north of Pit 4 after the January sampling. The second sampling event occurred in July 1999. In July 1999, 46 ports from Pit 4 and 137 ports from Pit 10 were sampled. All but one of the locations sampled in January over Pit 4 were sampled again in July. Samples were collected in Tedlar bags after purging and later analyzed using a Brüel and Kjaer photoacoustic gas analyzer for CCl_4, TCE, PCE, 1,1,1-TCA, and $CHCl_3$. While $CHCl_3$ was not listed as a component in 743-series sludge, it has been detected in the subsurface in relatively high concentrations. After the survey was complete, ports were removed from the ground.

There were several interesting results from the 1999 shallow soil-gas survey. First, the maximum concentrations (CCl_4 [7,260 ppmv], TCE [1,590 ppmv], $CHCl_3$ [1,550 ppmv], 1,1,1-TCA [208 ppmv], and PCE [141 ppmv]) were much higher than the maximum concentrations measured during the 1987 and 1992 surveys. This is true for both the January and July 1999 data. Another interesting result is that the maximums occurred at a location along the northern boundary of Pit 4 (see Figure 2, Location B8), with the exception of the maximum PCE concentration, which occurred over Pit 10 (see Figure 2, Location E18). These maximum concentrations were measured in July because the locations where they occurred were not sampled in January. Recall that Pit 4 Row B ports were installed after the January sampling event, and Pit 10 was not sampled in January.

In general, the concentrations measured in January 1999 were greater than the concentrations measured in July 1999. For example, of the 36 ports over Pit 4 that were sampled in both January and July 1999, 32 (90%) had higher concentrations of CCl_4 in January. As for the other VOCs, the percentage of ports that had higher concentrations in January was 75% (TCE), 76% (PCE), 81% (1,1,1-TCA), and (53%) $CHCl_3$. This suggests that the maximum concentrations for the 1999 survey would have been even higher if all the ports sampled in July had been sampled in January. Higher concentrations in January could be the result of frozen ground inhibiting releases to the atmosphere. The January and July data show a reasonable degree of correlation with correlation coefficients for the VOCs ranging from 0.53 to 0.64.

Figure 3 shows an isopleth map of CCl_4 concentrations from the July 1999 survey. In terms of "hot spot" locations, the results agree with previous surveys in that high concentrations are located at the western end of Pit 10 and the eastern end of Pit 4. However, this survey shows the concentrations in Pit 4 to be much higher than Pit 10. The higher concentrations in Pit 4 could be the result of differences in the timing of waste released from Pits 4 and 10, but are more likely due to the higher volume and density of waste in Pit 4. Miller and Varvel (2001) reported that 42.7% of the 743-series sludge drums in the SDA were buried in Pit 4 and concentrated in the east end. In contrast, only 14.5% of the 743-series sludge drums were buried in Pit 10 and those were spread out over a larger area.

Though no formal report was written, a basic report and data tables generated from the 1999 survey are included in Appendix C.

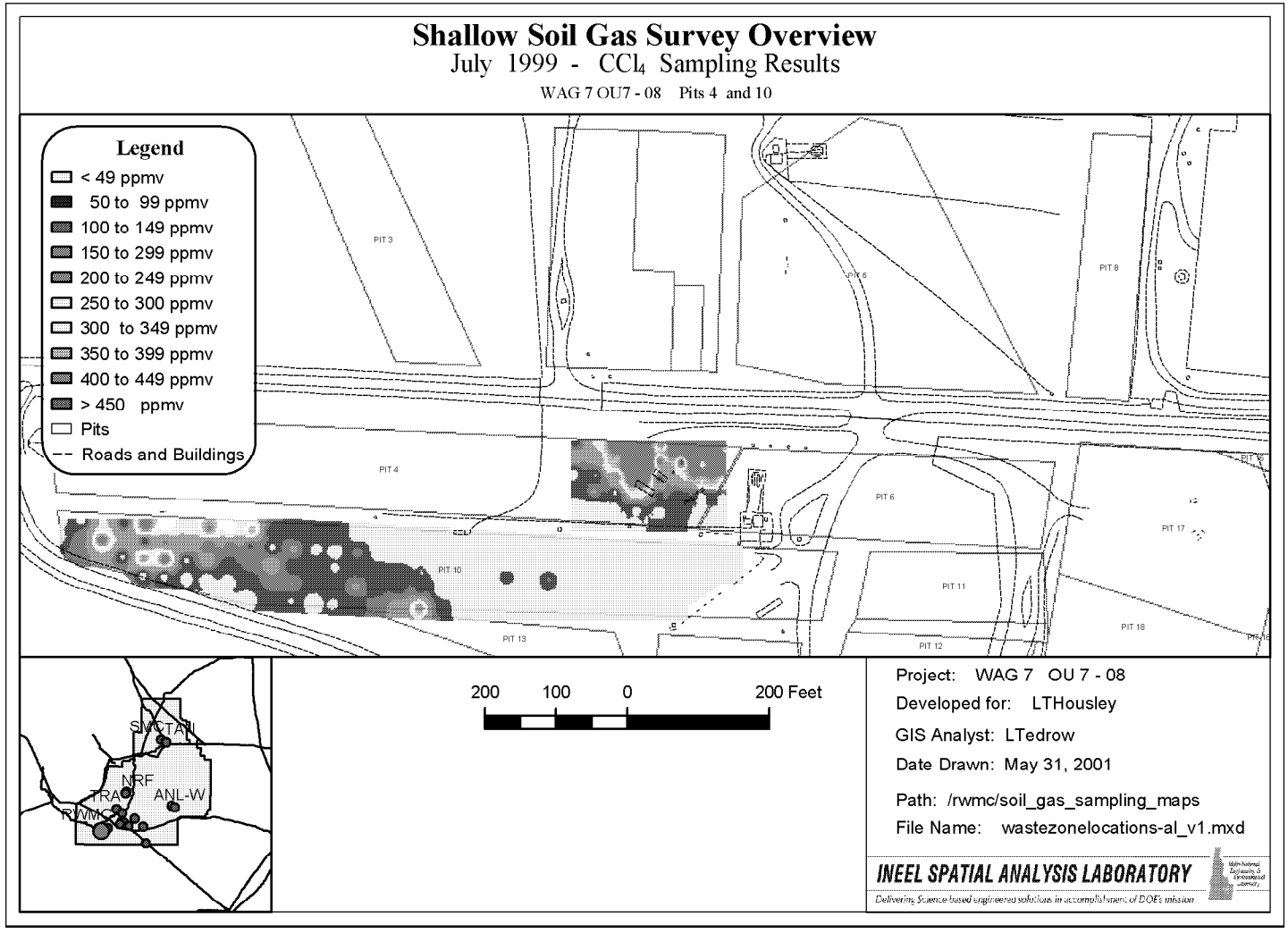


Figure 3. Carbon tetrachloride concentrations (ppmv) in soil-gas measured during the July 1999 shallow soil-gas survey.

5. 2000 SHALLOW SOIL-GAS SURVEY

The purpose of the 2000 shallow soil-gas survey was to obtain data for determining source release characteristics and verify new information obtained regarding burial locations of 743-series sludge. Like the 1999 survey, the 2000 survey sampled the eastern end of Pit 4 but only sampled the western end of Pit 10, whereas the 1999 survey sampled all of Pit 10. In addition, the 2000 survey sampled the surface over Pits 5 and 6 but used a coarser spacing (15 m [50 ft]) on Pit 5. The 2000 survey also included an additional row of ports north of the northern boundary of Pits 4 and 6. Finally, a transect consisting of three rows of tightly spaced ports was installed across a "hot spot" identified from the 1999 survey over the eastern end of Pit 4.

A grid containing 367 proposed sample port locations was developed for the 2000 soil-gas survey (see Figure 4). Because of accessibility problems and drilling difficulties, only 209 ports were installed and sampled. Installation and sampling occurred over a 3-month period from June 14 to September 7, 2000. Ports were installed in a similar manner to the 1999 survey, but a hydraulic power insertion probe was used rather than a hammer drill. The other significant difference was that the annulus of the access tubes were filled with sand and sealed with bentonite at the surface, whereas the tubes were not sealed for the 1999 survey. The sample ports installed for the 2000 survey were also left in place to be sampled in the future.

Concentrations measured during the 2000 survey were similar to the 1999 survey for areas common to both surveys. The maximum concentrations for the 2000 survey were as follows: CCl_4 (6,330 ppmv), TCE (2,270 ppmv), $CHCl_3$ (1,350 ppmv), 1,1,1-TCA (205 ppmv), and PCE (122 ppmv). Figure 5 shows the results of the 2000 survey for CCl_4. The highest concentrations were over the eastern end of Pit 4 with lesser concentrations dispersed over Pit 6 and the west end of Pit 10. Carbon tetrachloride concentrations in Pit 5 were confined to a relatively small area near the center of the pit.

The results of the 1999 and 2000 surveys show good correlation with a map of 743-series waste drum disposal locations produced later by Miller and Varvel (2001) (see Figure 6). For example, the CCl_4 results over Pit 5 from the 2000 survey (Figure 5) are comparable with 743-series waste burial locations in Figure 6. In addition, both the 1999 (Figure 3) and 2000 survey results (Figure 5) show a strong correlation with the disposal locations shown in Figure 6. The high level of agreement between the survey results and the 743-series waste burial locations suggest that VOCs are still being released from buried waste and the source is sufficient to create spatial plumes that closely correlate with the original disposal of 743-series waste drums.

Appendix D contains a report of the 2000 shallow soil-gas survey data and corresponding maps for CCl_4.

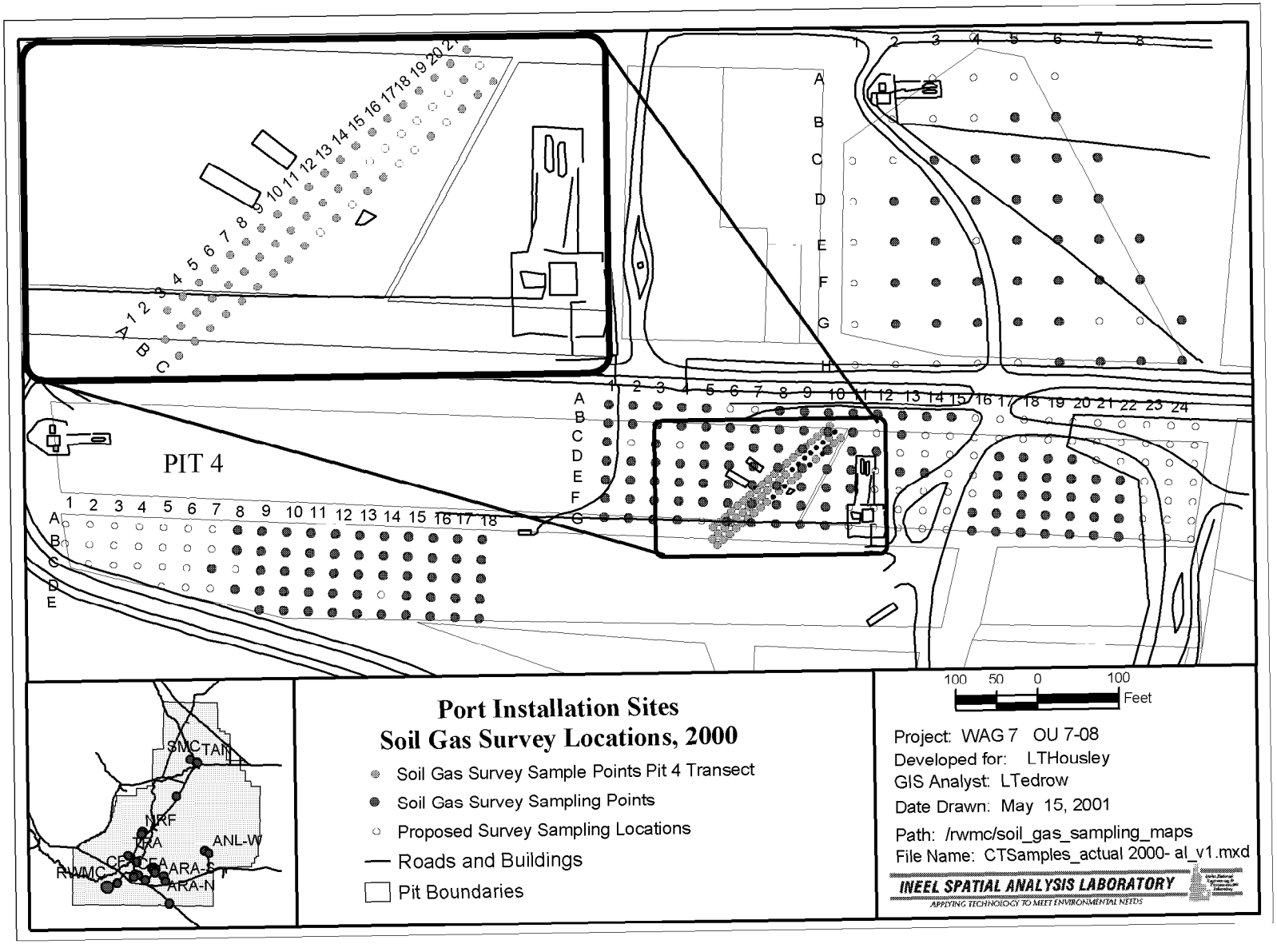


Figure 4. Carbon tetrachloride port locations during the 2000 shallow soil-gas survey.

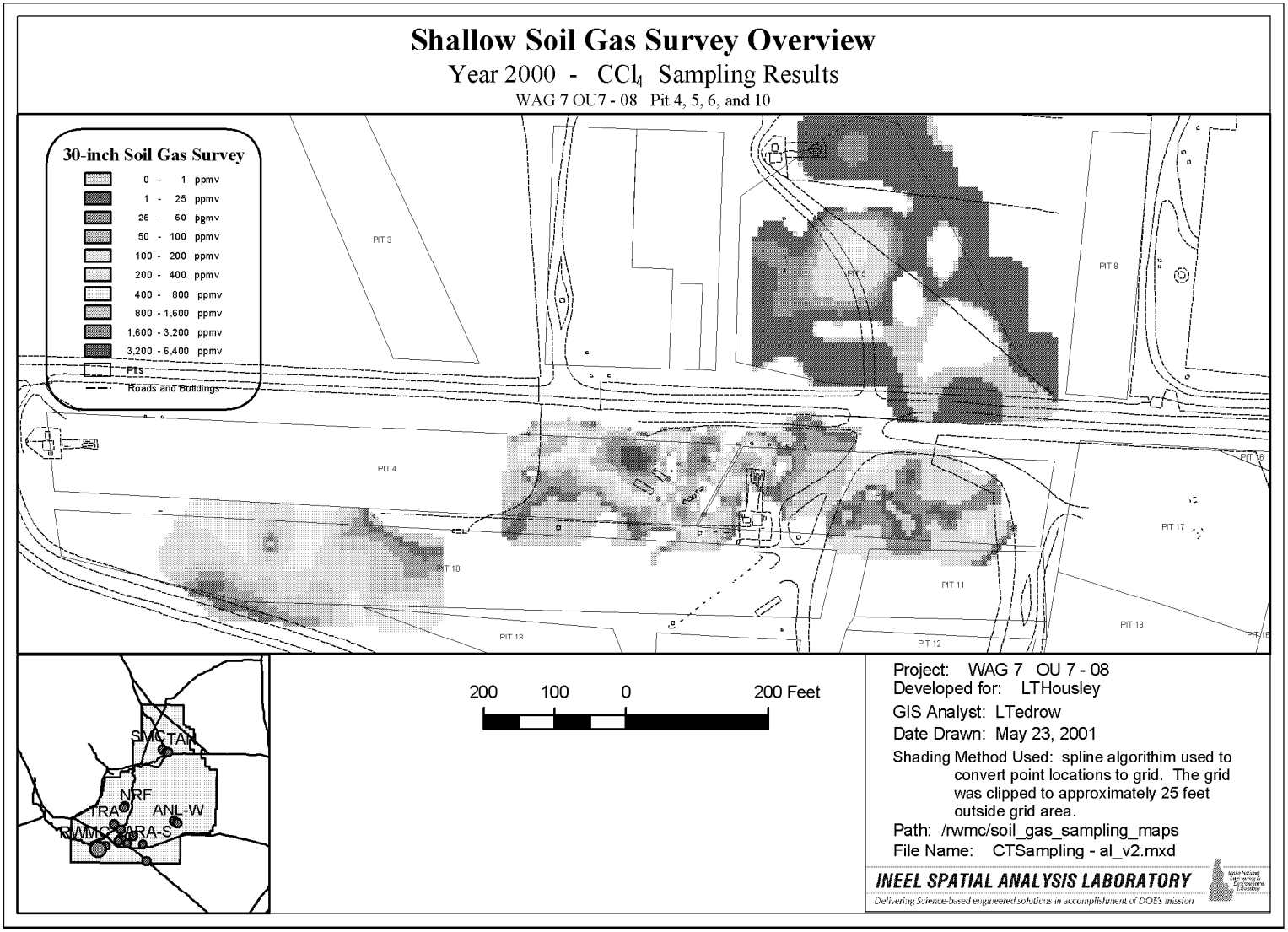


Figure 5. Carbon tetrachloride concentrations (ppmv) in soil-gas measured during the 2000 shallow soil-gas survey.

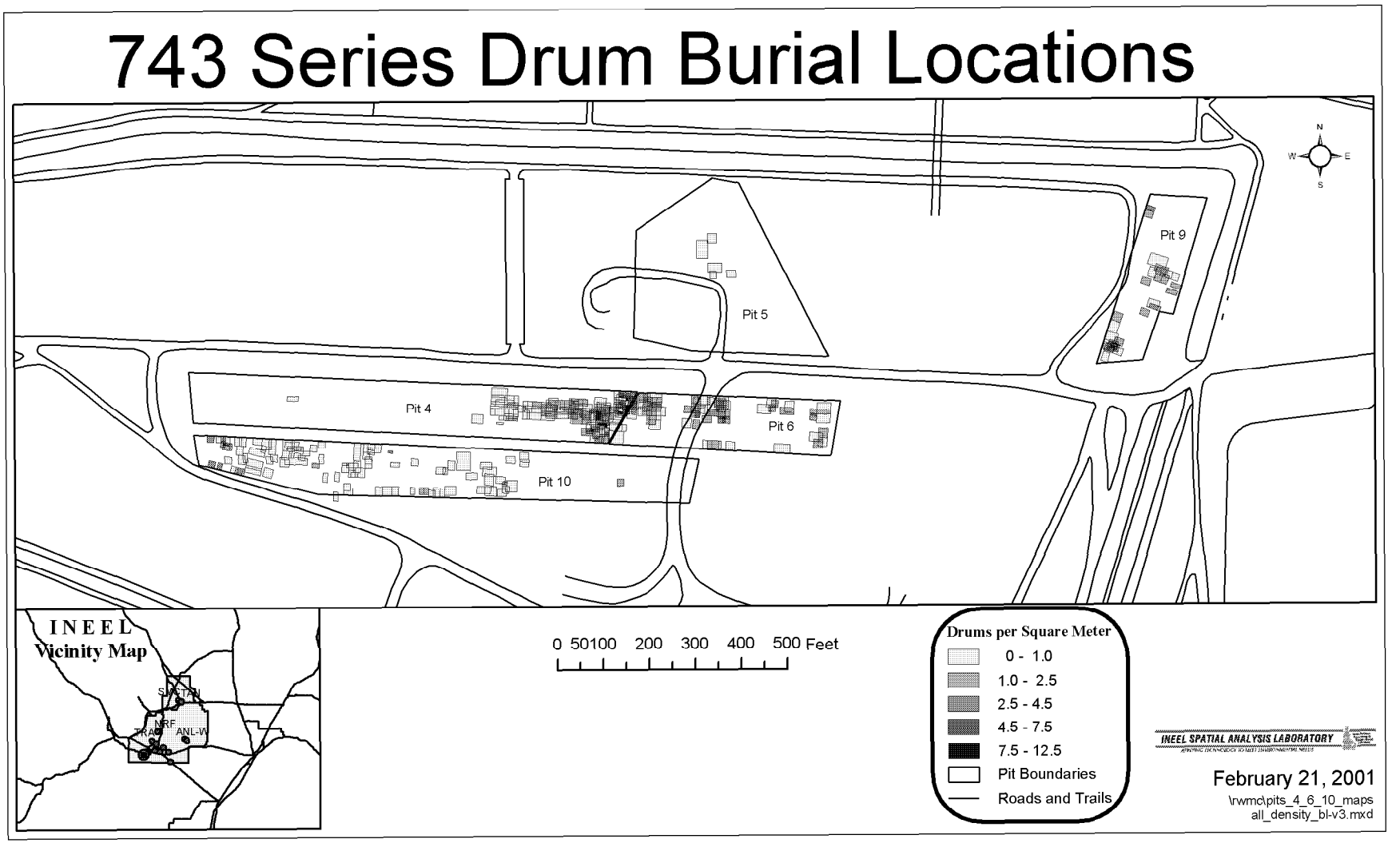


Figure 6. Burial locations of 743-series sludge drums (from Miller and Varvel 2001).

6. 2001 SHALLOW SOIL-GAS SURVEY

The objectives of the 2001 shallow soil-gas survey were to 1) obtain data to validate or negate the presence of CCl_4 in the eastern end of Pit 2 detected during the 1992 survey and, 2) determine, if possible, the effects of probe installation on subsurface CCl_4 release. Port installation and subsequent sampling occurred from October 31 through November 8, 2001.

6.1 Pit 2 Survey Results

A grid containing 37 sample port locations over Pit 2 was developed for the 2001 soil-gas survey (see Figure 7). Ports were installed in the same manner as the 2000 survey. Samples were analyzed using a Brüel and Kjaer photoacoustic gas analyzer for CCl_4, TCE, PCE, 1,1,1-TCA, and $CHCl_3$, but it should be noted that CCl_4 was the main contaminant scrutinized in this survey.

The maximum CCl_4 concentration detected during the 1992 survey was 111 ppmv over the eastern end of Pit 2. CCl_4 results from the 2001 survey ranged from 1.0 to 20.0 ppmv. Based on a comparison of 1992 and 2001 survey results, it was concluded that there is no significant source of CCl_4 remaining in Pit 2 relative to other locations within the SDA. The single, moderately-high detection of CCl_4 in 1992 was possibly caused by fluctuating natural conditions, error in sample collection and analysis, or failure of an isolated drum coincident with sampling.

6.2 Effects of Probe Installation

Since December 1999, more than 200 probes of different types and function have been driven through the waste zone in several areas of the SDA. Approximately 60 of these probes were installed in the area of the 743 transect in the eastern end of Pit 4. It is suspected that the process of driving these probes could increase the release of VOCs by penetrating an intact 743-series drum or disturbing VOC-laden sludge, if either existed. If it was determined that VOC releases were affected by probing, this would be additional evidence that the pits at the SDA are still an active and viable source of VOCs. It may also yield information useful for remediating the source.

In order to determine the possible effects of probe installation on CCl_4 release in the SDA, sampling of the ports along the transect over Pit 4 was conducted again in November 2001 (see Figure 4). Recall that the ports along the transect were first sampled in 2000 about a month prior to probe installation. Probes were installed along the transect area from August 31, 2000, through October 8, 2001. Because some of the original ports along the transect area were damaged during the probe installation process, several had to be re-installed in locations as close as possible to the originals. Comparisons of CCl_4 concentrations along the transect in 2000 and 2001 are shown in Figure 8.

Upon reviewing this information and comparing it to the dates when probes were installed in the respective area (see Figure 9), no correlation could be made in regard to probe installation and subsequent CCl_4 releases from the waste zone. Note that the concentration spike in transect A from the 2000 survey is in close proximity to the concentration spike in transect C from the 2001 survey. Although probes were installed in the general vicinity of the spike in transect C the previous month, there were no probes installed in the vicinity of the spike in transect A prior to the 2000 survey. Also, there were probes installed in the same timeframe that were close to other sampled ports but showed no increased concentrations. Therefore, the probe installations could have had an effect on the release of CCl_4 in the SDA, but this survey was inconclusive in proving such a phenomenon. More frequent sampling around specific probe installations could have produced more conclusive results.

Appendix E contains a report of the 2001 shallow soil-gas survey data for CCl_4.

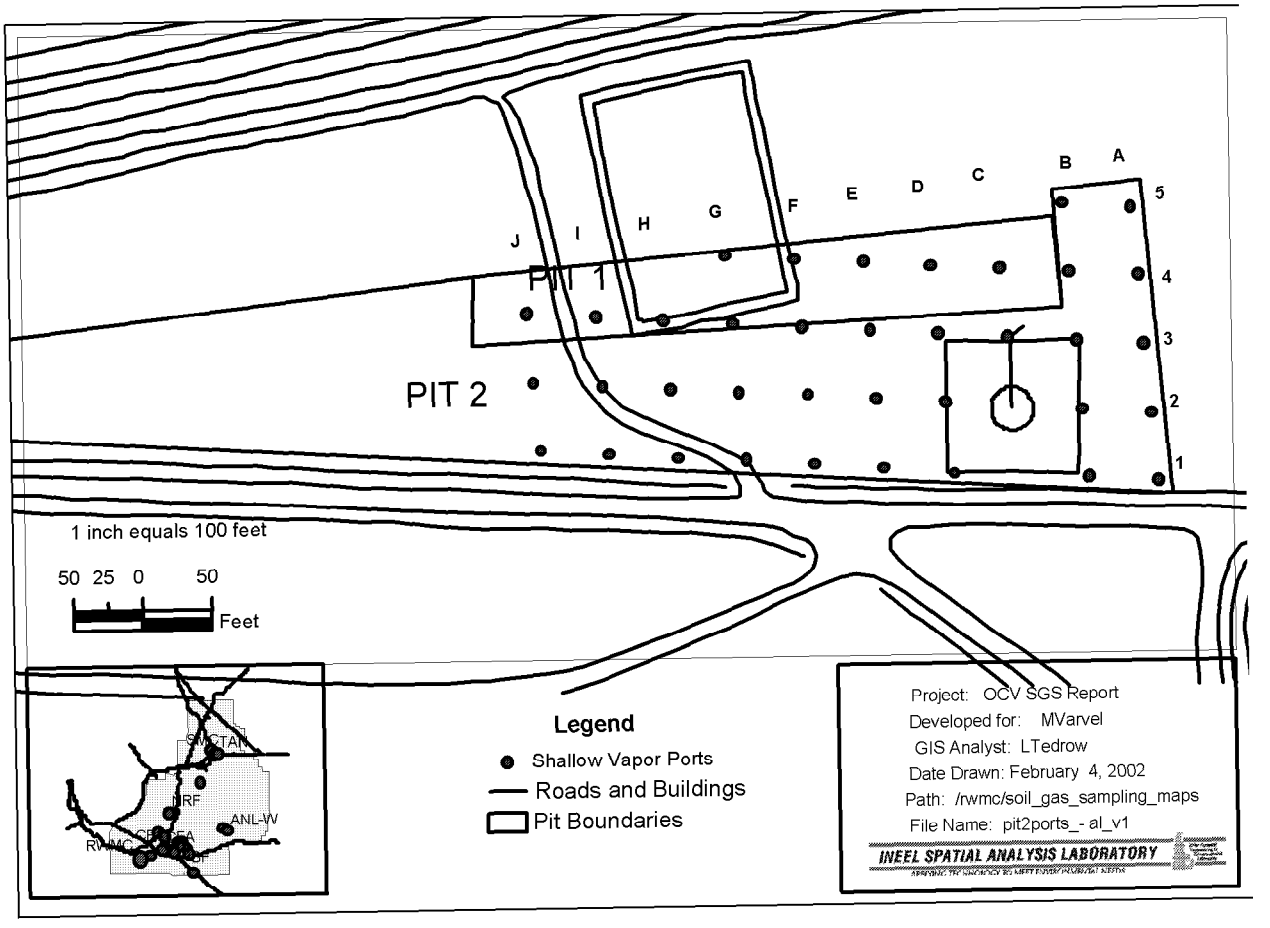
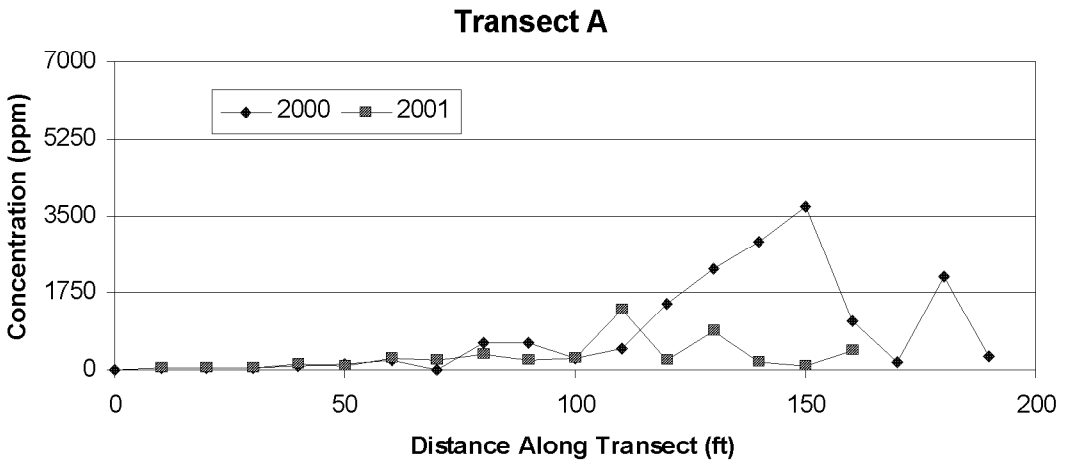
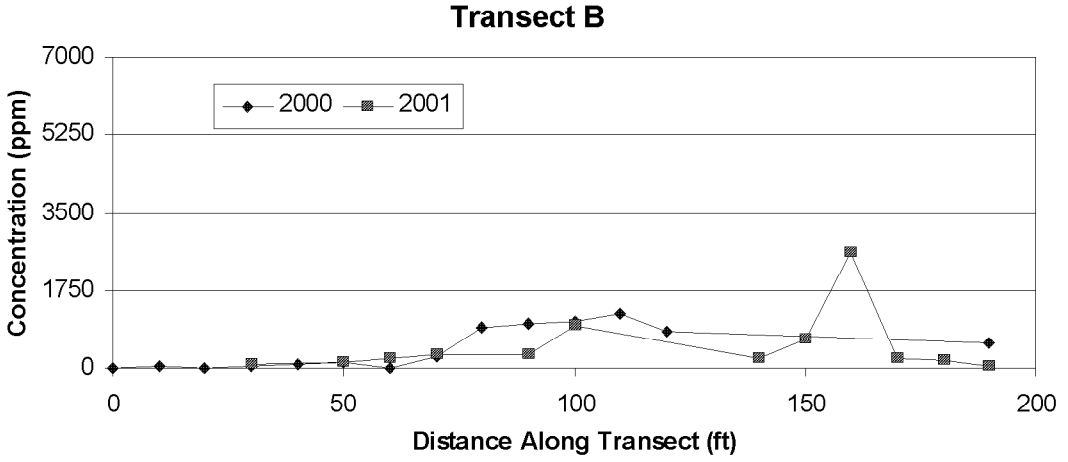


Figure 7. Plot showing shallow soil-gas port locations installed over Pit 2.





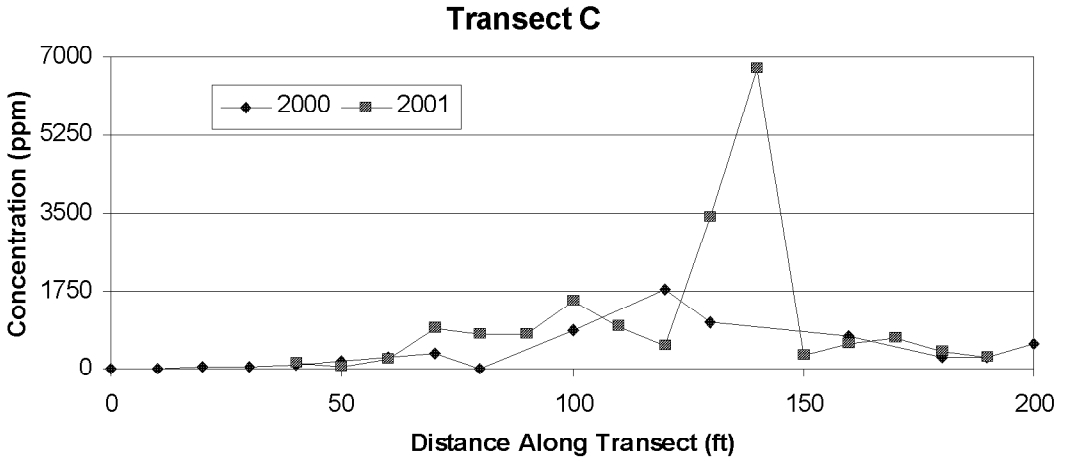


Figure 8. Plots comparing CCl_4 concentrations from the 2000 and 2001 shallow soil-gas surveys for transects A, B, and C in the SDA.

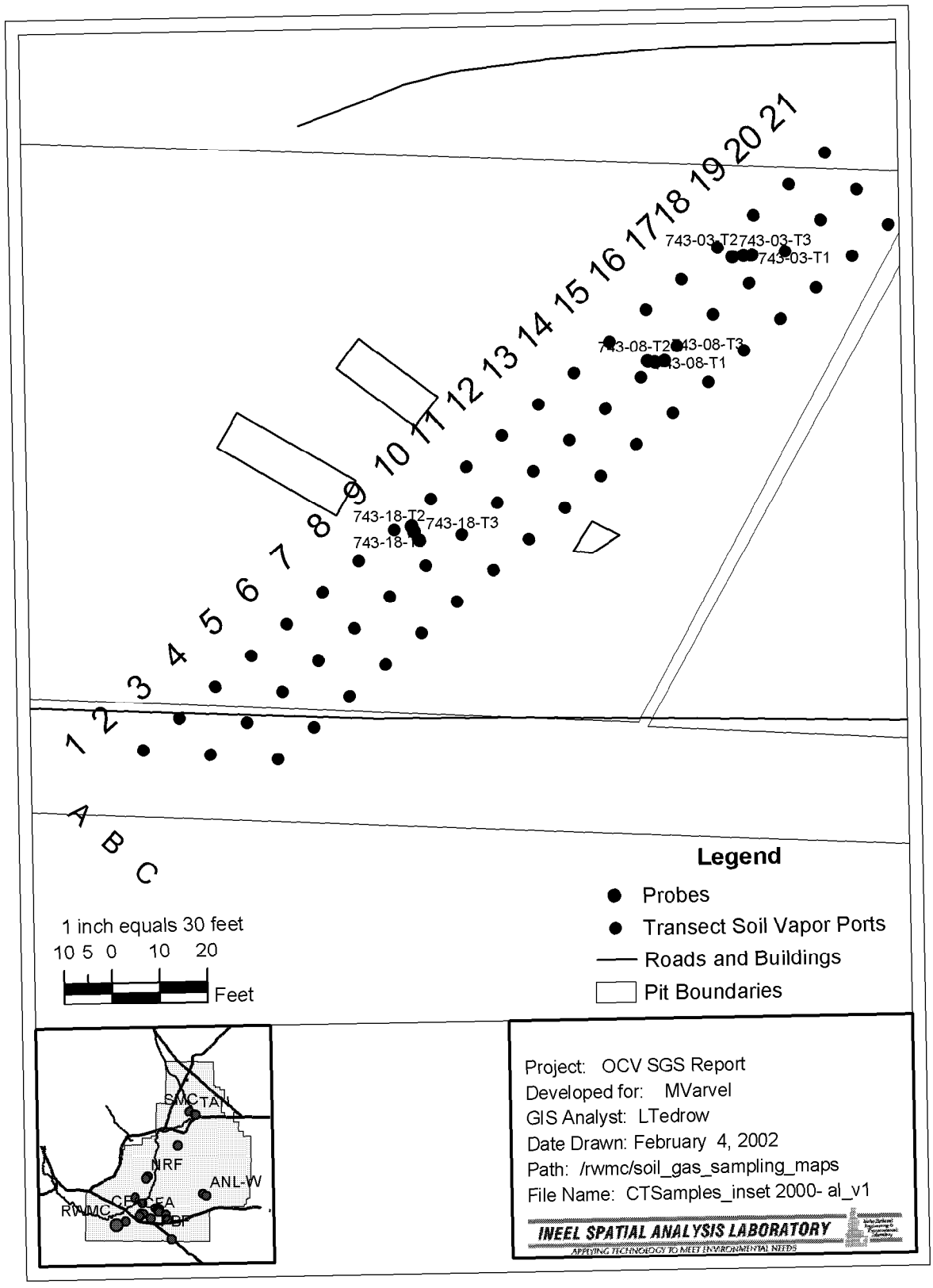


Figure 9. Map showing the transect port locations and probes installed in the vicinity approximately 1 month prior to the 2001 shallow soil-gas survey.

7. SUMMARY

Five shallow soil-gas surveys have been performed at the SDA. The first two surveys conducted in 1987 and 1992 covered large areas using a relatively coarse spacing. The results were useful for determining general VOC waste burial locations. The surveys conducted in 1999 and 2000 used a finer spacing and were focused over specific pits, or portions of pits, identified by the previous surveys to contain VOC waste. The 1999 and 2000 surveys helped determine "hot spot" locations within pits and establish baseline conditions for future surveys to determine general changes in source release characteristics for 743-series sludge. However, it should be noted that a "high resolution" survey, similar to those performed in 1999 and 2000, has not been performed over Pit 9, in which 13.2% of the 743-series waste drums were reported buried (Miller and Varvel 2001). Data from the 2001 survey provided evidence that Pit 2 is not a significant source of VOCs, as data from the 1992 survey might suggest. Data from the 2001 survey, however, were inconclusive in relating CCl_4 source release to probe installations.

8. CONCLUSIONS

Overall, the results of the five surveys concur with one another in terms of identifying hot spots and burial locations of VOCs contained in 743-series sludge. Any differences in the results of the five surveys described in this report are likely the result of variations in how the surveys were conducted (e.g., port installation methods, sample locations, and analysis techniques). Weather and seasonal effects, which cause changes in air pressure, temperature, and soil moisture are other factors that can cause results to differ, not only between surveys but also during a survey. These environmental variations make it difficult to duplicate the surveys with a high degree of precision, which should be taken into account when making quantitative comparisons. Nonetheless, if future surveys are conducted, efforts to minimize differences during and between surveys will reduce data variability and increase our ability to discern trends in source behavior. The schedule and validity for conducting future surveys will be developed based on the results obtained from probes recently installed over pits in the SDA.

9. RECOMMENDATIONS FOR FUTURE DATA

As data from previous soil-gas surveys have been useful in identifying source locations and characteristics, data from vapor probes installed in the waste and future soil-gas surveys, when coupled with previously collected data, will be useful in understanding source behavior. Recommendations for future shallow soil-gas investigations are discussed below.

It is recommended that future shallow soil-gas surveys be developed based upon a thorough evaluation of past soil-gas data and data to be collected from vapor probes installed in the waste. If it is determined that all pertinent information can be obtained through probe samples, there would be no need to conduct additional surveys. On the other hand, depending on the data that the probes can reliably collect, future surveys may be very useful in correlating probe data and extrapolating conclusions about release over larger areas such as those covered during a shallow soil-gas survey. The frequency of such surveys would largely depend on the validity of the probe data results and would not specifically be determined until probe data has been fully scrutinized.

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